ORIGIN OF MAGNETIC LINEAR PATTERN ON MARS. G. Kletetschka, P. J. Wasilewski, A. Borosio, and P. T. Taylor, GSFC/NASA, Greenbelt, 20771, Maryland, USA; gunther@denali.gsfc.nasa.gov.

Introduction: The recent discovery of significant crustal magnetization [1,2] in the southern highlands, manifest as east-west trending magnetic anomalies, has major implication for the early evolution of Mars. We located the magnetic anomaly maxima and minima and visualize the pattern as continuous throughout the southern highlands, thus a planet wide signature. Large impact basins significantly modify the magnetization pattern. The derived magnetization contrast requires a thickness of 30 km of Martian crust having a uniform magnetization up to 20 A/m [2]. We analyze possible magnetic carriers and their concentrations in a 30 km thick crust required to generate the observed pattern. We propose a simple model of Martian history explaining the magnetic patterns.

Magnetic minerals: There are three abundant magnetic minerals with potential to carry significant remanent magnetization. These minerals are magnetite, pyrrhotite (common on earth and in the SNC meteorites) and hematite. Magnetite and pyrrhotite can hold significant thermoremanence only when in the single domain (SD) state represented by grain size generally smaller than 1 µm [3]. Below the SD threshold magnetic remanence decreases with decreasing grain size down to a size that would become thermally unstable. Magnetic remanence of larger multidomain (MD) grains rapidly decreases with grain size due to domain interactions [3]. In contrast, thermoremanence, in hematite, increases with grain size even for grains larger than 0.1 mm in diameter due to the weaker influence of self-demagnetization [4].

The very different TRM behavior of MD hematite in contrast to magnetite is due to two factors. The first is the lesser influence of magnetostatic self-energy with respect to wall pinning energy, at temperatures almost up to the Curie temperature for hematite. The second is the greater importance of the magnetostatic energy in the applied field, which for hematite dominates the total energy at high temperatures. Thermal blocking only occurs just below the Curie temperature in MD hematite, because of the large volume associated with Barkhausen moments in such grains. Thus this mechanism provides for large magnetic stability in hematite grains at temperatures close to Curie temperature.

Pyrrhotite has Curie temperatures close to 320 C, Magnetite and hematite exhibit a range of Curie temperatures (200-570 C and 500-670 C respectively) depending on the amount of Ti in the mineral. TRM intensity is about the same for SD magnetite, SD pyrrhotite and MD hematite [5]. TRM intensities of MD magnetite, MD pyrrhotite and SD hematite are also comparable, but much lower [5]. These mineralogical considerations are necessary because we presently do not know what is responsible for the martian crustal magnetization and hematite has been identified.

Concentration producing the magnetic contrast: Magnetic contrast estimated for the magnetization model requires certain values of [magnetization x volume =20 A/m x 30 km]. Given the TRM values of magnetic minerals acquired in a 40 A/m external field we can estimate mineral concentrations required to produce the observed magnetic contrast. Consequently as a result of this consideration when we homogeneously disperse magnetic mineral in a 30 km thick crust we obtain between (0.1 to 1)% of SD magnetite and/or SD pyrhotite and/or MD hematite (see Fig 1).

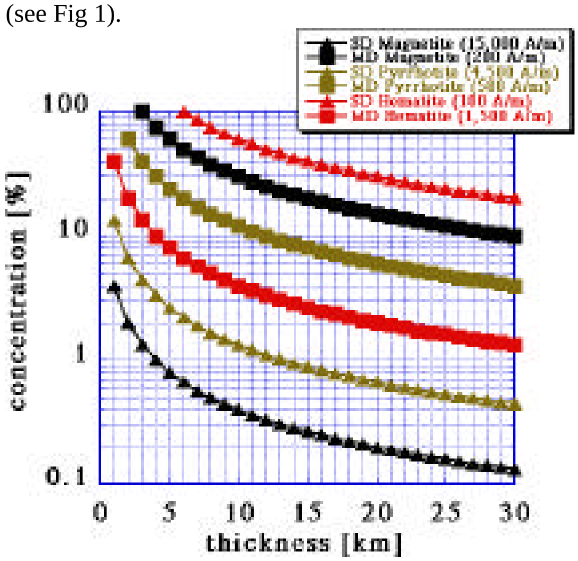

Fig. 1:

Magnetic pattern distribution: The three component magnetic vector record detected during the aerobraking period by MGS and the absence of a present-day global field means that the significant magnetic anomalies were acquired, during the existence of an ancient dynamo which ceased to function at some point in time, but left the thermoremanent magnetization record as evidence. The radial magnetic component has been analyzed in a way that allows location of the maxima and minima (see Fig. 2).

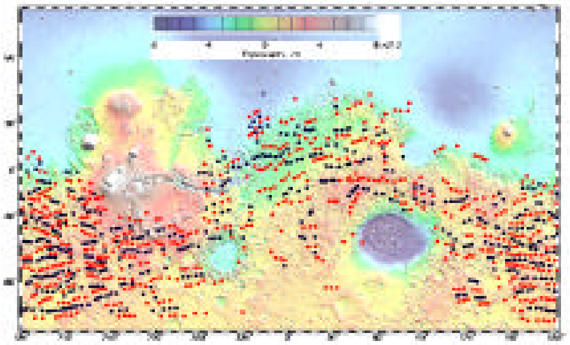

Fig. 2:

The resulting pattern map is overlain on the topography produced by Mars Orbiter Laser Altimeter (MOLA) [8]. The total image reveals that the magnetic lineation pattern extends beyond the area described in [2] and is contiguous with all of the southern highlands with the exception of an area near the south pole. The large impact basins, Hellas and Argyre, figure prominently in the modification of the magnetic patterns. This image suggests a continuity of the alternating polarity pattern throughout the southern highlands and trending quasi-parallel to the dichotomy boundary. We interpret this preliminary observation as evidence of once accumulated terranes possessing different remanent magnetization contrasts.

Tectonic model: A process that can account for the observations implied in the magnetic patterns favors significant mantle upwelling on one side and downwelling on the opposite side of the hemisphere similar to the Mars convection model with two exothermic phase transitions [6]. A model with a perovskite layer decreasing in thickness over time above the core-mantle boundary can account for a peak in volcanic and magnetic activity early in Martian history [7] (see Fig. 3).

Fig. 3:

This system may produce less dense non-subductable terranes forming the southern highlands. This process is schematically illustrated in Fig. 4. (For presentation purpose the appearance of Mars is oblate ellipsoid).

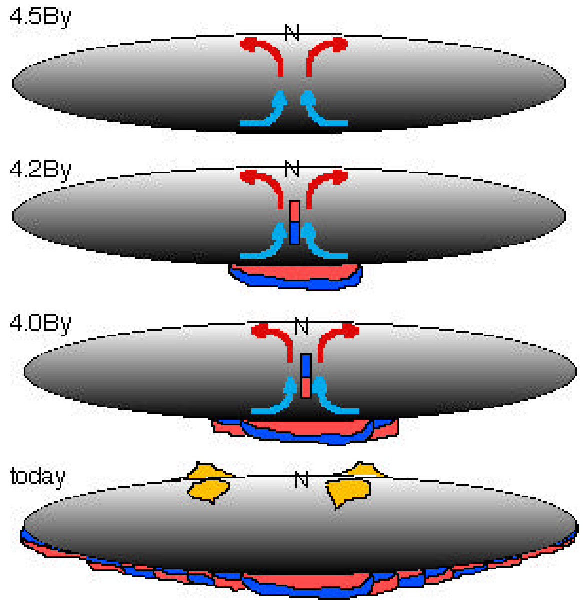

Fig. 4:

Magnetic dynamo is active and magnetizes the early crust in one direction. Fluctuation of magnetic field strength and/or magnetic reversals modifies the remanent magnetization of the new crust being differentiated and emplaced in the southern highlands. Early depletion of the low-density mantle material as well as depletion of the perovskite layer near the core mantle boundary [6] stops the mantle convection. Heat accumulated in Northern lowlands activates extensive superplume activity forming the late volcanism (Tharsis and Elysium).

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